Net Force and Vertical Motion

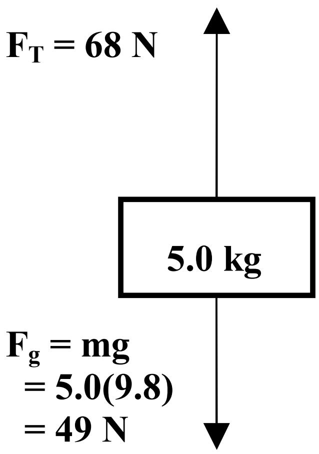
We'll start by examining objects where the unbalanced force acts ***vertically***.

Set up by following these steps:

- draw a free-body diagram (f.b.d.) showing all relevant forces acting on the mass;
- next, write out the freebody equation, relating all forces to $\mathbf{F_{Net}}$;
- finally, substitute all given information and solve for the unknown quantity.

Note that if the force is larger than the weight, the mass accelerates *upward*; if the force is smaller that the weight, the mass accelerates *downward*.

Consider the diagram below, showing a 5.0 kg mass being pulled upward by a rope with a tension force of 68 N.



In this case it can be seen that the net force will act *upward*, so choose **up** as positive.

→ $\mathbf{F_{Net}}$ **= 68 - 49 = 19 N** (upward)

→ then: $\mathbf{F_{Net}}$ **= ma**

19 = 5.0a

a = 3.8 m/s² $\mathbf{a = 3.8\ m/s^2}$ (upward)

Example #2. A 25.0 kg mass is pulled upward vertically by a force of 183 N. Find the acceleration of the mass.

(see Dynamics Ex 2 for answer)

Elevator Problems.

In its simplest form, an elevator moves and accelerates vertically up and down, just like the problems previously discussed. And like these problems, this motion is due to the tension force in a cable pulling up, and the force of gravity pulling down on the elevator itself. If the values of these forces are known, the acceleration of the elevator can be easily determined using the methods shown above. Or, if the acceleration is known, an unknown force can be determined in the same manner.

Example #3. What is the tension if the cable of an elevator of mass 550 kg that is accelerating upwards at the rate of 4.5 m/s^2?

(see Dynamics Ex 3 for answer)

At the same time, we can also analyze the motion of an elevator by examining the forces that act on a person *inside* the elevator as it moves up or down.

You should be able to find the <u>apparent</u> weight of someone in the elevator when it is *accelerating upwards*, *decelerating upwards*, *accelerating downwards* and *decelerating downwards*. It is also possible to find the tension force in the cable under these conditions.

The *apparent weight* is the reading that would appear on a bathroom scale if the person were standing on it, inside the moving elevator. This is simply the *normal force* exerted by the elevator floor (and the scale) upward on the person's feet.

The passenger feels *heavier* when accelerating upwards <u>or</u> decelerating downwards because the floor of the elevator must not only support her weight, but also supply an accelerating (or decelerating) force. In this instance, $\mathbf{F_N} > \mathbf{F_g}$.

Conversely, the passenger feels *lighter* when decelerating (slowing down) upwards <u>or</u> accelerating downwards because part of her weight is being used to supply the accelerating force, leaving less normal force on her feet. It is as if the floor is “falling” away from her feet; in this case, $\mathbf{F_N} < \mathbf{F_g}$.

To solve this type of problem, it is important to recognize that there are only <u>two</u> vertical forces acting on the passenger:

- the normal force of the bathroom scale (pushing upward);
- the force of gravity, i.e., her weight (pulling down).

By drawing a free-body diagram showing these forces, and recognizing the direction of the elevator’s acceleration (and net force), you can determine the apparent weight (i.e., normal force) for any passenger inside.

Example. #4. A 50.0 kg student is riding an elevator while standing on a bathroom type scale. Find the scale reading when the elevator is:

a) **accelerating upwards at 0.50 m/s^2.**
b) **traveling upwards, but decelerating at 1.0 m/s^2.**
c) **accelerating downwards at 0.75m/s^2.**

(see Dynamics Ex 4 for answer)

Note that $\mathbf{F_N} < \mathbf{F_g}$ in both (b) and (c), because acceleration is ***downward***.

Example. #5. A 90 kg person stands on a bathroom type scale in an elevator as it accelerates downwards. If the scale reads 85 N, at what rate is the elevator accelerating?

(see Dynamics Ex 5 for answer)